# ADAPTIVE POWER CONTROL OF INK MELT HEATERS FOR UNIFORM INK MELT RATE

## BACKGROUND

[0001] The present exemplary embodiments relate to printing systems and, in particular, printing devices which utilize a supply of colored inks to be communicated to a print head for document printing. More particularly, the present embodiments utilize solid ink sticks as the supply ink, which must be heated to a liquid form before being capable of communication to the print head. Such systems are commercially available under the PHASER® mark from Xerox Corporation.

[0002] The present embodiments concern the structure, control system and operation methods of the heater element for causing a phase change in the solid ink supply to a liquid form capable of fluid communication to a print head for document printing.

[0003] The basic operation of such phasing print systems comprises the melting of a solid ink stick, its communication to a reservoir for interim storage, and then a supply process from the reservoir to a print head for printing of a document. The object of the control strategy is to avoid the printing system running out of ink while trying to print, because such an event can be a catastrophic failure to the system. Prior known systems will typically supply a measuring device in the reservoir to monitor ink levels therein. When the ink drops below a certain level due to normal usage, then the ink supply control system would melt more of the solid ink supply until the reservoir would refill to the desired level. The steps of asking for more ink, turning on the melter to melt the solid ink, delivering the ink to the reservoir to a desired level and then turning the heater off is commonly referred to as an "ink melt duty cycle." It is an operating feature of such systems that as the frequency of melt duty cycle changes, the flow rate characteristics of the heating system will correspondingly change. For higher frequency duty cycles, the melt rate goes up; for lower frequencies, the melt rate goes down.

[0004] Conventional systems used a fixed applied power supply to the heater that was predetermined to provide a desired melt rate, but since only one level of applied power was available, the actual melt rate could vary depending upon consequential ambient variant conditions or varying printing operations, i.e., a high

demand of certain ink color versus a low demand of another ink color would result in different frequencies of the melt duty cycles for the different colors. Where the printing system is printing an unusually large amount of a particular color, the corresponding increase in frequency of the ink melt duty cycle similarly may have a consequence on the desired flow rate, that is, the supply ink may be heated to a higher temperature than normally expected before the start of a next duty cycle due to failure to have enough cool down times between the cycles. Additionally, it is not unusual for such printing systems to be employed in out of office environments such as in an unheated storage warehouse in a colder location to an uncooled airplane hangar in a desert location. Extreme ambient temperature conditions such as these examples can have an effect on the flow rate in a heating process where the heating element receives only a single level of applied power.

**[0005]** There is a need for an improved adaptive control system for the power supply for such ink melt heaters that can avoid the variances of ink melt rates resulting from consequential variant conditions. Improved precision in ink flow rate control provides consequent efficiencies in ink handling, i.e., less heat losses, smaller reservoir requirements and less heating of ink therein over shorter periods of time. The present exemplary embodiments satisfy this need as well as others to provide an adaptive power control system for ink melt heaters in phasing printing systems that can provide a substantially uniform ink melt rate. However, it is to be appreciated that the present exemplary embodiments are also amenable to other like applications where the supply of power to the heating element needs to be adjusted for enhanced control of items heated by the heater element.

## BRIEF DESCRIPTION

**[0006]** A method and system is provided for selectively controlling supplied power to an ink melt heater for maintaining a desired ink melt rate despite a varying ambient parameter affecting an actual melt rate. A predetermined amount of power is initially supplied to the ink melt heater intended to cause the desired ink melt rate. An ambient parameter is detected to the ink melt heater that will likely have a consequential effect on a desired ink melt rate in view of the predetermined amount of power supplied to the ink melt heater. If the detected ambient parameter is determined to cause enough of a variance in the actual melt rate from the desired

ink melt rate, the supplied power is adjusted from the predetermined amount to an adjusted amount for realizing the desired ink melt rate. The ambient parameter may comprise sensing a factor representative of either local environmental air temperature or ink temperature adjacent to the ink melt heater.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** FIGURE 1 is cross-sectional view in partial section of a print head, ink stick and ink loader assembly, and power supply and control system therefor;

**[0008]** FIGURE 2 is an end view of one embodiment of a heater melt plate;

**[0009]** FIGURE 3 is a flow chart of the control steps for adjusting applied power to the ink melt heater; and

**[0010]** FIGURE 4 is a graphical representation of a correction factor versus monitored temperature applied to the applied power in accordance with the subject control strategy.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

**[0011]** With reference to FIGURE 1, the basic elements of an ink supply system in an ink "phase-changing" printing system can be seen. Ink loader assembly **10** includes a tray **12** for holding a solid phase ink stick **14**. An ink melt heater **16** is disposed at an open end **18** of the tray to contact the ink stick and to allow for egress of liquid phase ink during heating from the tray **10**. The heating plate **16** receives its heating energy from a power supply and control system **20**. The heating element includes an assembly with resistance traces thereon so that electrical energy supplied thereto can be converted to heat energy.

**[0012]** With particular reference to FIGURE 2, power pads **30** connect wires (not shown) from the power supply to the heat plate **16**. The plate includes a first portion **32** disposed to engage the ink stick and phase change the solid ink stick to a liquid. A heated liquid ink zone **34** then allows the liquid ink to flow to an ink drip point **36**. It should be appreciated that the embodiment shown in FIGURE 2 comprises the side of the heater element having the heat traces shown. The ink stick will actually contact the element comprising a metallic heat plate on a back side from that shown in FIGURE 2. A rivet hole **38** is used to attach the assembly of heat traces to the metallic plate.

[0013] FIGURE 1 shows an ink drip **40** falling from the tray **10** and the heating element **16** assembly into a print head assembly **42**. Print head assembly **42** comprises a reservoir **44** to receive the melted ink and to communicate the ink to nozzles (not shown) within the print head assembly for printing on a document. It should be appreciated with reference to FIGURE 1 that the ink stick **14** is intended to engage the heat plate **16** as it is shown therein by being urged against the plate by gravity or a spring biased member (not shown) to enhance its contact between the stick **14** and the plate **16**.

[0014] It is an advantageous feature of the present embodiments that a more uniform ink melt rate can be achieved for the filling of the reservoir **44** from the loader assembly **10** by adaptive power control of the ink melt heater **16**. Such adaptive power control will make the ink melt rate largely independent of frequency variations in the ink melt duty cycle, starting ink temperatures of the solid ink stick **14** and local ambient temperature variations.

[0015] The present embodiment comprises an algorithm that monitors the ink temperature and/or local ambient temperature, next to the heater and computes a correction coefficient that adjusts the supply power to the heater prior to the melt cycle. FIGURE 2 shows a thermistor device **50** associated with the plate **16** through thermistor pads **52**. The thermistor device is operatively connected with the control system **20** to provide a signal representative of a plate temperature near the location of the thermistor. The thermistor is thus disposed on a fin portion **60** of the plate spaced from the ink melt zone **32**. Although the thermistor device **50** is illustrated in the present embodiment for measuring a parameter representative of temperature, other well know temperature sensing devices could be employed, i.e., thermometers, electrical sensors, chemical sensors or the like. The temperature sensed by the thermistor can be a parameter indicative of ambient temperature to the system or the ink stick temperature prior to the start of a melt duty cycle.

[0016] The amount of applied heater power which is desired to be applied by the system **20** to the heating element **16** is a function of convection losses plus the energy to melt/mass ratio multiplied by a desired melt rate. By convection losses is meant the heater power losses to the local environment which is a function of local ambient temperatures (referred to in FIGURE 3 as "Ta") Energy to melt/mass comprises the total energy to melt ink per unit mass and is a function of ink

temperature (referred to in FIGURE 3 as "Ts"). Applicants have found that a temperature at the plate of approximately 100°C will generally produce the desired melt rate, i.e., an appropriate drip flow into the reservoir **44**.

**[0017]** As noted above, the preferred embodiments comprise a smart algorithm that delivers precisely the amount of energy as needed for each melt cycle depending on the current ambient temperature and bulk supply ink temperature. To correct for the ink starting temperature, an ink temperature correction factor (ITCF) is applied, which is calculated as follows:

$$\text{ITCF} = 1\text{-Cp}^{*}\ \text{Mf}^{*}(\text{Ts-Ta})/(\text{Heater Power}\ ^{*}\%\ \text{Power Applied}) \tag{1}$$

Cp = average specific energy of solid ink between (30°C-70°C)

Mf = ink melt rate when Ts=Ta

Heater Power = Total heater wattage

% Power applied = % of heater wattage require to maintain Mf

**[0018]** To correct for the local ambient temperature effect, an environmental temperature correction factor (ETCF) is computed as follows:

$$\begin{aligned}&\text{ETCF} = 1\text{-Ha}^{*}(100\text{-Ta})/(\text{Heater Power}\ ^{*}\ \%\ \text{Power Applied})\\&\text{Ha} = (\text{Heater Power}^{*}\%\text{Power Applied} - \text{Mf}^{*}\text{heat of melt/mass of ink from Ta})/(100\text{-Ta})\end{aligned} \tag{2}$$

**[0019]** The corrected power to the heater thus comprises ITCF * ETCF * Heater Power * % Power Applied. Full cool down time from an ink duty cycle is approximately 45 minutes to an hour. In the present embodiment, the thermistor device is assumed to read the ambient temperature from the ink melt heater plate when the heater has not been powered in the last 45 minutes from a previous duty cycle.

**[0020]** With particular reference to FIGURE 3, a flow chart illustrating steps of the present embodiments is shown. Once the ink melt heater is turned on **70**, the control system will monitor the temperature of plate **72**, which is considered to be

the starting temperature of the ink stick prior to the start of the melt cycle (Ts). At the same time, the predetermined amount of power to the ink melt heater is applied **74** and the temperature of the plate is monitored **76**. If the monitored temperature is determined to be not greater than 100°C, then the full applied power signal is continued as indicated by return line **78**. If the plate temperature monitored by the thermistor is greater than 100°C, then the ink temperature correction factor is calculated and the amount of power is further calculated **82** to maintain the desired flow rate. As long as the ink melter duty cycle continues in the step that the ink melter should be on **84**, the temperature of the plate is monitored **86**. So long as the temperature is less than a predetermined limit (for example, if the plate temperature were suddenly to spike up indicating a system failure) **88**, then the power continues to be applied **90**. The power will be applied until the system determines that the ink melter should be turned off **84**, such as by the completion of the duty cycle or the refilling of the reservoir, and the system will exit **92**. Block **94** indicates that when the temperature exceeds the predetermined limit, the power for the heater plate is turned off.

**[0021]** With reference to FIGURE 4, an exemplary embodiment of the applied correction factor is graphically seen as a function of the monitored melt plate temperature. It can be seen therein that as the melt plate temperature appreciably increases over what is considered to be normal ambient office temperatures, a reduction in applied power will result from the application of the correction factor.

**[0022]** It can be seen that the subject embodiments comprise detecting an ambient parameter to the heater plate device which will affect the actual melt rate of the ink stick when power is applied to the plate for the melting of the solid ink. It is only when the detected ambient parameter is perceived to cause a variance in the actual ink melt rate from the desired ink melt rate that the power to the heater plate needs to be adjusted. In the present embodiments the parameters that are monitored have been illustrated to comprise ambient temperature to the system or an increased temperature of the solid ink stick engaging the plate due to the lack of full cool down time to the system. A timer is disposed within the control circuit **20** for timing the elapsed time from a completion of a previous melt cycle. When the timer has not timed out a proper cool down elapsed time, it is assumed that the thermistor

is detecting the starting temperature of the ink stick. The thermistor detects ambient temperature after the timer has timed out the cool down period.

**[0023]** The exemplary embodiments have been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the exemplary embodiments be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

CLAIMS: